PV PERFORMANCE AND YIELD COMPARISONS: NREL SAM AND PVSYST

JUNE 2012

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AGENDA

- Compare energy yield, performance results, and the reports between two recognized PV simulation tools. How do they compare in the areas of key interest?
- This short presentation will not compare to actual collected field data from our monitored sites. Nor is this presentation a tutorial on the tools. Focus will be more on the engineering side rather than the financial.
- NREL's System Advisor Model (SAM) is a leading application (freely available) that has evolved over many years. Does more than PV including numerous renewable sources such as solar thermal and geothermal
- PVSYST is a PV-centric simulation tool developed initially at the University of Geneva, Switzerland. Now a standalone company.
- Both tools will work for simulating systems anywhere in the world.

QUICK OVERVIEW

- **Both SAM and PVSYST will report on the most important engineering results:**
  - Energy yield (and the specific production (normalized))
  - Performance Ratio
  - Loss breakdown
- **The level of detail varies with PVSYST focusing more on the engineering aspects of design and deployment; SAM provides good engineering control with a tremendous amount of financial parameter manipulation and reporting (including LCOE analysis)**
- **PVSYST focuses on year one with extensive reports and breakdowns; since SAM provides multiyear economic analysis, it takes into account annual degradation**
- **Both tools allow extensive loss parameter entry (including custom shading)**

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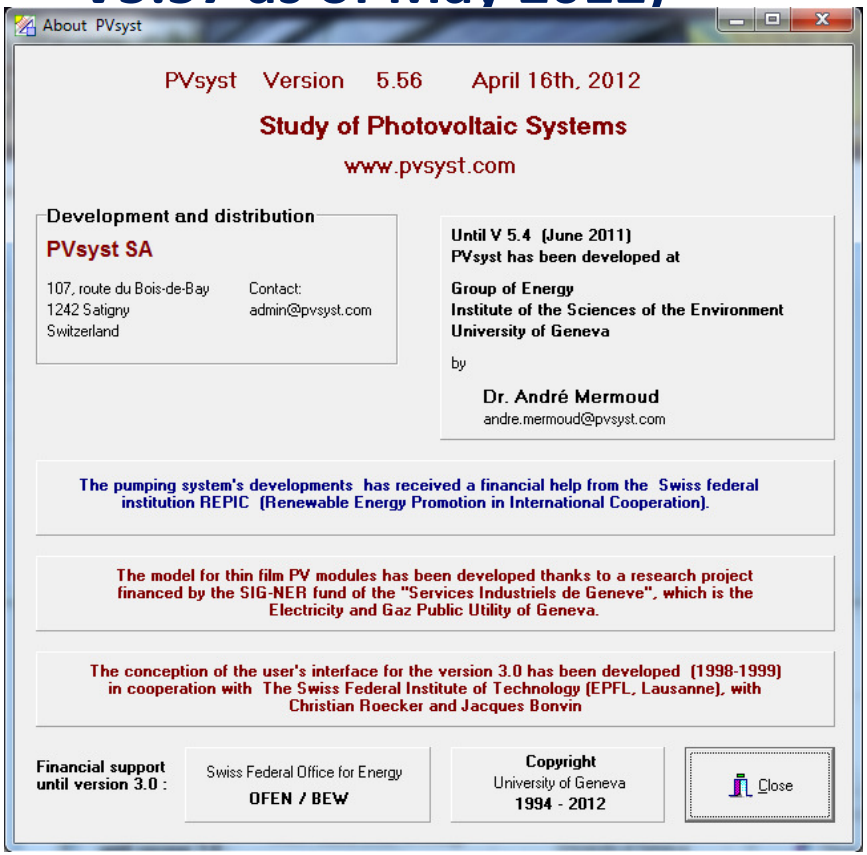
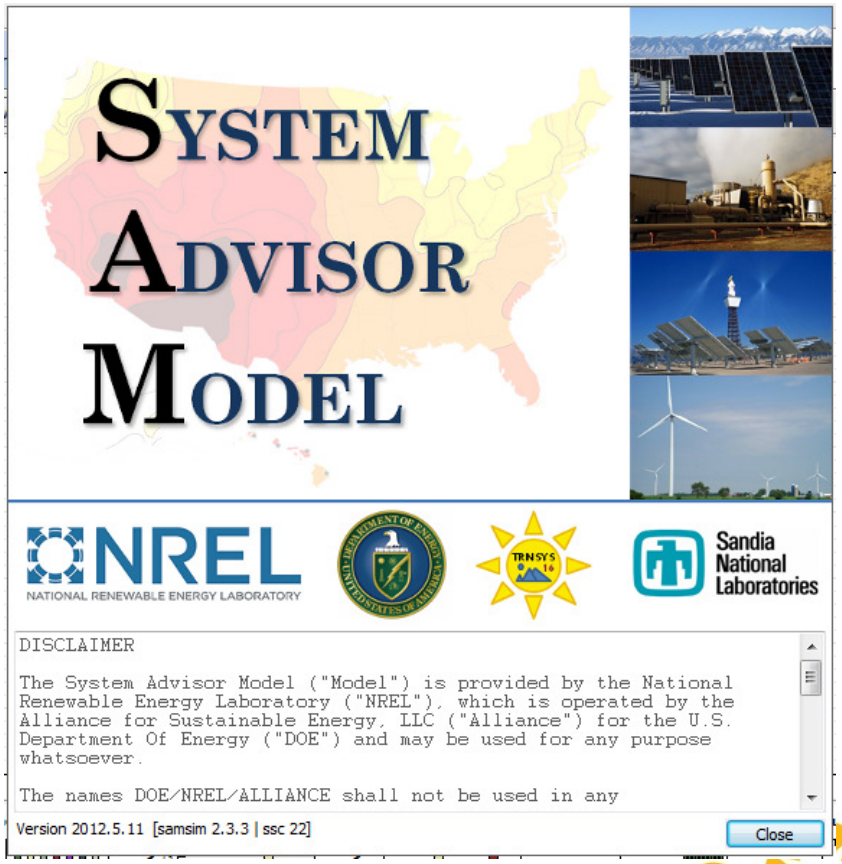
TOOL VERSIONS

- **SAM version 2012.5.11 (this is the latest)**
- **PVSYST version V5.56 (latest as of April 2012; new minor release V5.57 as of May 2012)**





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1 MW Commercial Modeling Example

- 1 MW Suniva 250W OPTIMUS monocrystalline system
- 4004 panels with a string size of 14 (286 strings)

	SAM 2012.5.11	PVSYST 5.56
Climate file	Atlanta Hartsfield Airport TMY3	Atlanta Hartsfield Airport TMY3
Tilt	30 degrees	30 degrees
Azimuth	180 (due south)	0 (due south) (Northern Hemisphere centric)
NOCT	46 C	46 C
DC Wire Ohmic loss at STC	1.0%	1.5%
AC wire Ohmic loss at STC	0.5%	0.5%
Diode and connector loss	0.5%	N/A
Module efficiency loss/nameplate	0%	0.1%
Power loss at MPP/mismatch	2.0%	2.0%
Soiling loss annual	2.0%	2.0%
Degradation per year	0.5%	N/A
Availability per year	98%	N/A
Shading	0%	0%

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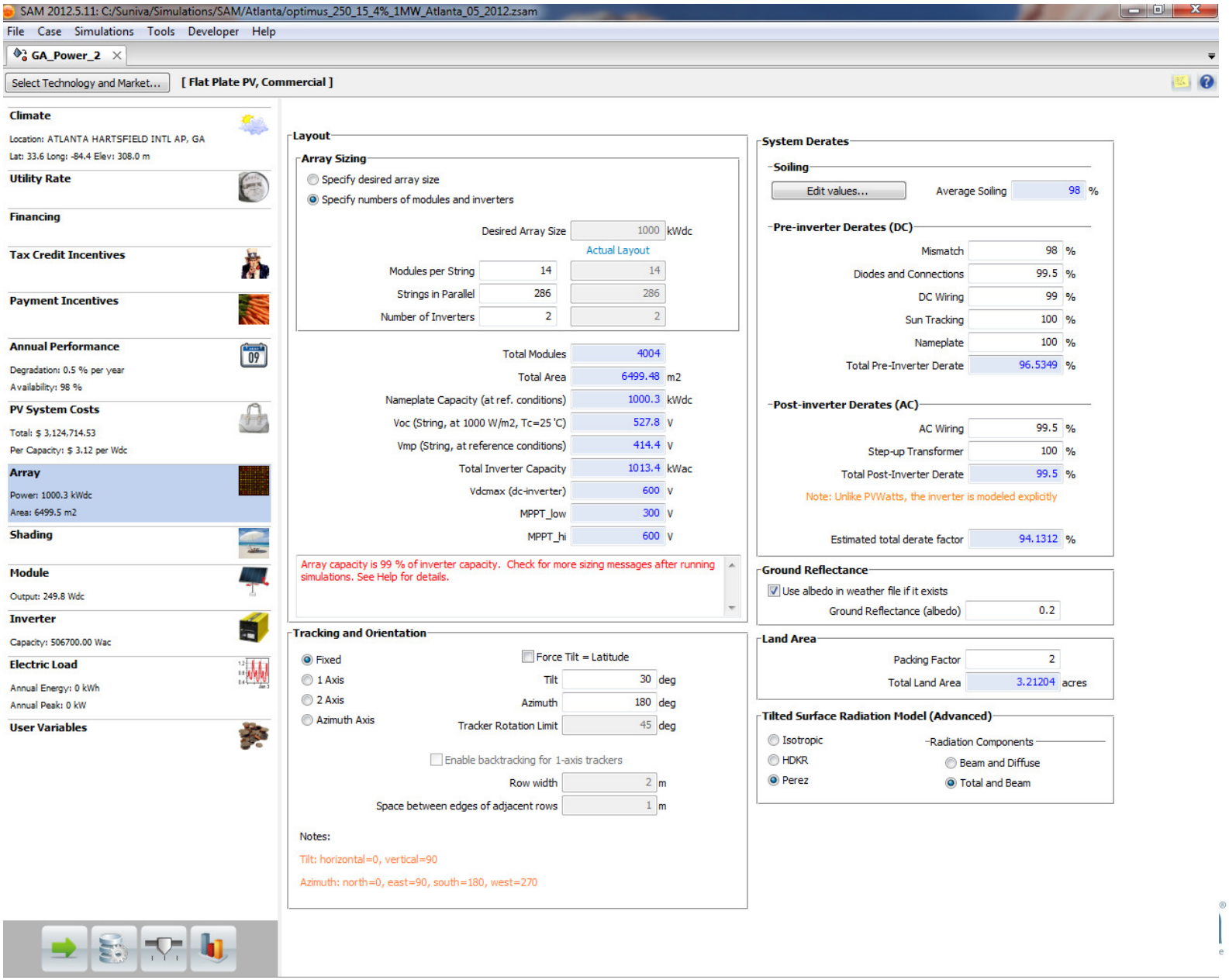
SAM WALKTHROUGH

Main PV array screen



SAM Report – parameter and results Summary

Key points are highlighted with key parameters

System Advisor Model Standard Report SAM 2012.5.11 Tue Jun 05 17:56:55 2012

SAM Report: Photovoltaic System with Commercial Financing

System Design and Costs

Nameplate Capacity: 1000.3 kWdc
Installation Cost: $3,124,715, 3.1 $/Wdc
Debt Fraction: 100.0 %

Location:
ATLANTA HARTSFIELD INTL AP, GA
33.6 deg N, -84.4 deg E, -5 GMT

Array Area: 6,499 m^2
Inverters: 2
Modules: 4,004
Strings: 286
Tracking: Fixed
Backtracking: No

Results

Annual Output: 1,586,206 kWh
Capacity Factor: 18.1 %
Performance Factor: 87.8 %

LCOE (nominal): 16.2 cents/kWh
NPV: Net Present Value: $-308,966
Payback Period: 13 years

Model Options

Module: CEC User Specs
Inverter: Sandia
Model Shading Effects: No
Financial Model: Commercial

Modules: User Specified CEC Model
Inverters: SAM/Sandia Inverters/SMA America: SC500U 480V [CEC 2009]
Weather file: C:\Suniva\Simulations\WeatherData\Atlanta_Airport/Atlanta_Airport_722190TY.csv

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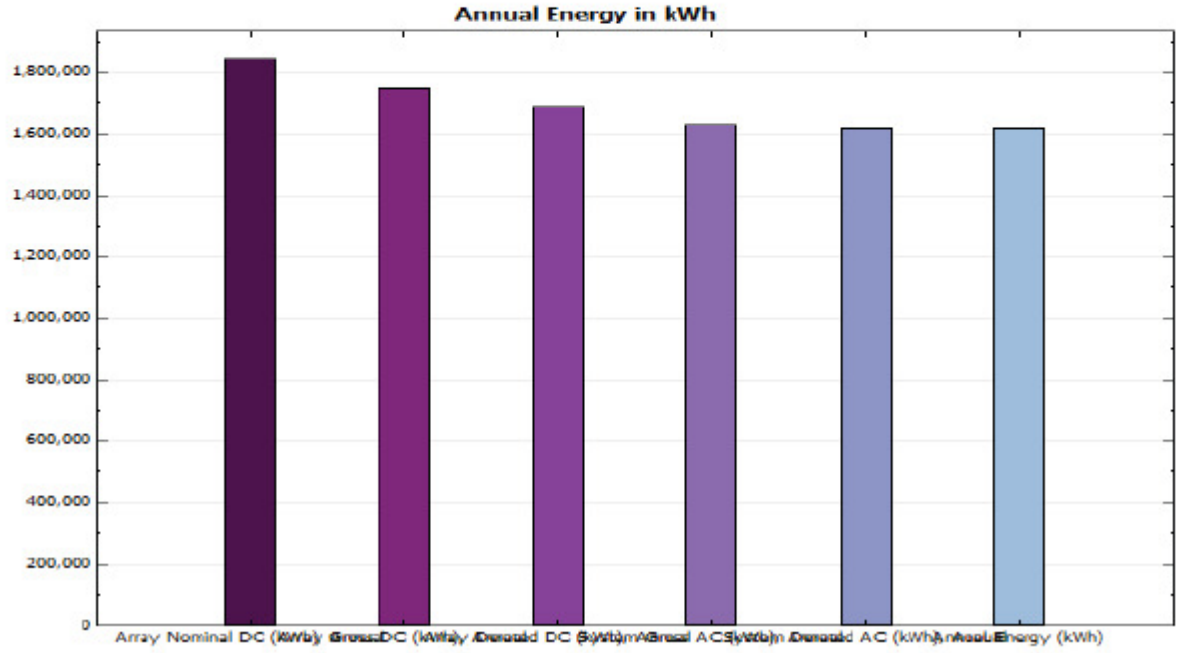
SAM REPORT – LOSSES

Losses and derate are shown as a function of loss in annual energy

Annual Energy in kWh with Losses as Percent of Nominal DC Output

Total Incident Radiation	11,984,539		
Nominal DC Output	1,844,468		
Gross DC Output	1,745,828	-5.3 %	Module losses
Derated DC Output	1,685,334	-3.3 %	DC derate losses
System Gross AC Output	1,626,711	-3.2 %	Inverter losses
System Derated AC Output	1,618,577	-0.4 %	AC derate losses
AC Energy Delivered to Grid	1,586,206	-1.8 %	Availability factor losses



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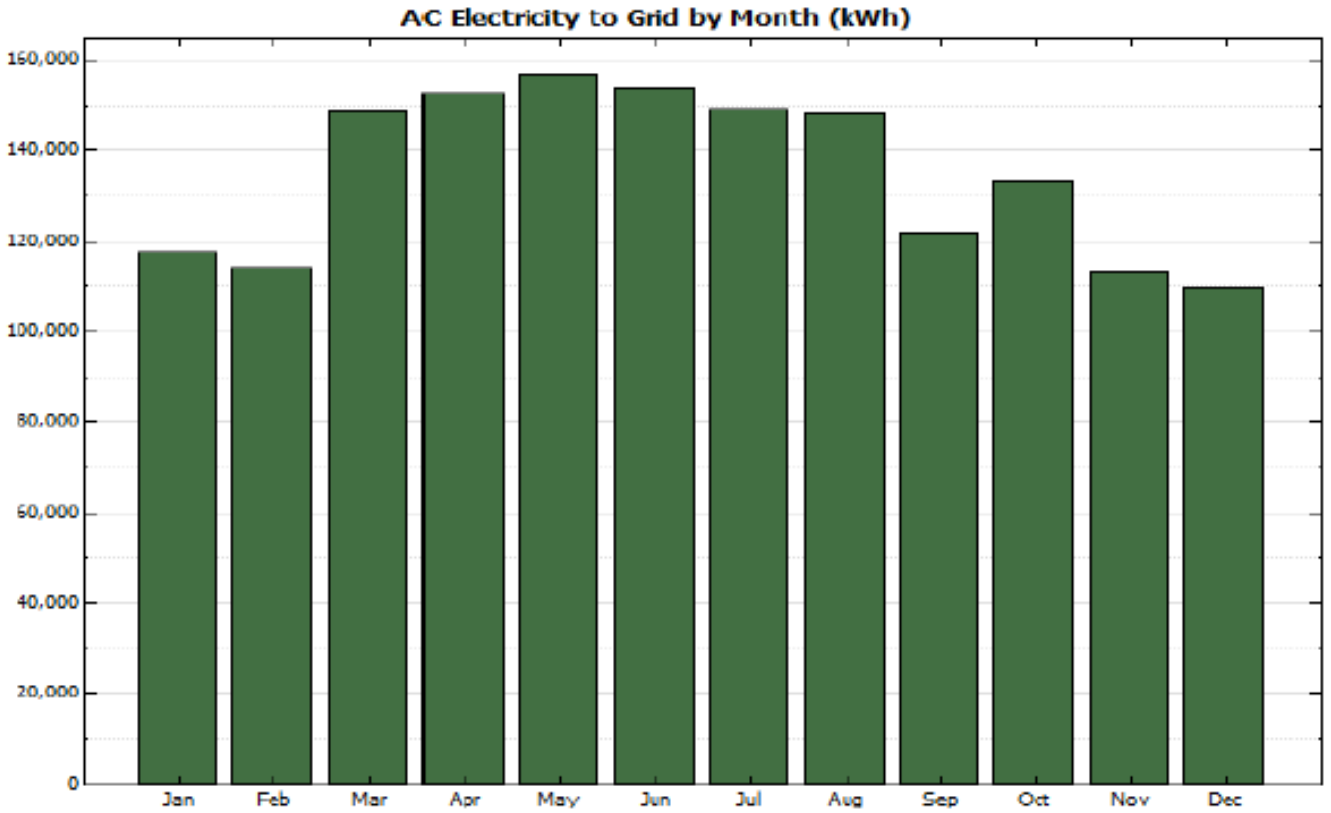
SAM REPORT – MONTHLY YIELD

Monthly yield is easy to follow



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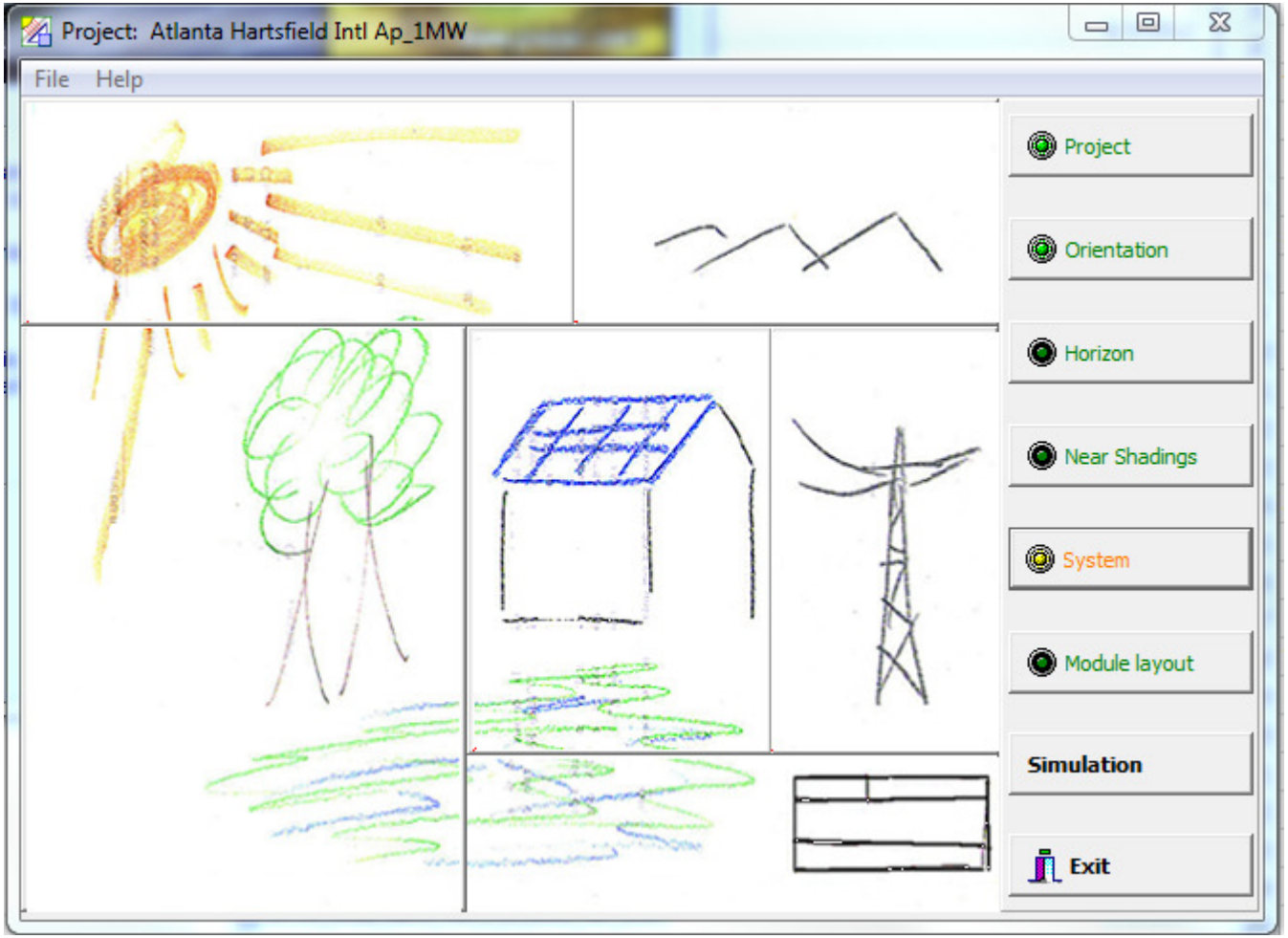
PVSYST WALKTHROUGH

Main grid-tie systems screen



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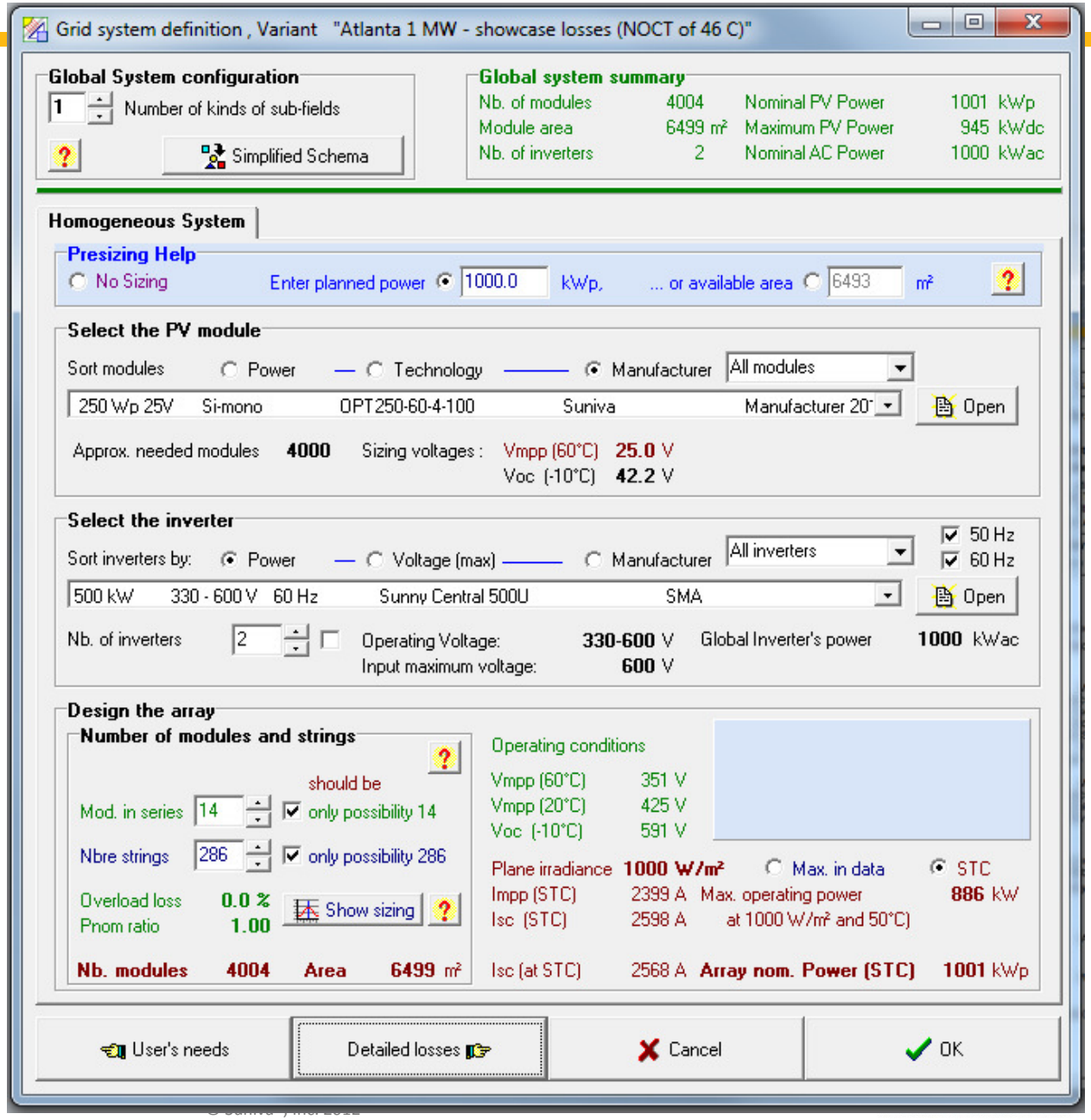
PVSYST WALKTHROUGH

Main PV array entry screen



PVSYST REPORT – PARAMETER SUMMARY

All parameters are shown so system simulation can be reproduced by a 3rd party independently

PVSYST V5.56		05/06/12	Page 1/3

Suniva: OPT250

Grid-Connected System: Simulation parameters

Project :	**Atlanta Hartsfield Intl Ap_1MW**				
Geographical Site		**Atlanta Hartsfield Intl Ap**		**Country**	**USA**
Situation		Latitude	33.6°N	Longitude	84.4°W
Time defined as		Legal Time	Time zone UT-5	Altitude	308 m
		Albedo	0.20		
Meteo data :	Atlanta Hartsfield Intl Ap, NREL TMY3				
Simulation variant :	**Atlanta 1 MW - showcase losses (NOCT of 46 C)**				
		Simulation date	05/06/12 17h41		

Simulation parameters

Collector Plane Orientation		Tilt	30°	Azimuth	0°
Horizon		Free Horizon			
Near Shadings		No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**OPT250-60-4-100**		
		Manufacturer	Suniva		
Number of PV modules		In series	14 modules	In parallel	286 strings
Total number of PV modules		Nb. modules	4004	Unit Nom. Power	250 Wp
Array global power		Nominal (STC)	**1001 kWp**	At operating cond.	886 kWp (50°C)
Array operating characteristics (50°C)		U mpp	369 V	I mpp	2399 A
Total area		Module area	**6499 m²**		
Inverter		Model	**Sunny Central 500-HE-US**		
		Manufacturer	SMA		
Characteristics		Operating Voltage	330-600 V	Unit Nom. Power	500 kW AC
Inverter pack		Number of Inverter	2 units	Total Power	1000 kW AC

PV Array loss factors

Thermal Loss factor		Uc (const)	27.7 W/m²K	Uv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (G=800 W/m², Tamb=20°C, Wind=1 m/s.)				NOCT	46 °C
Wiring Ohmic Loss		Global array res.	2.6 mOhm	Loss Fraction	1.5 % at STC
Array Soiling Losses				Loss Fraction	2.0 %
Module Quality Loss				Loss Fraction	0.1 %
Module Mismatch Losses				Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization		IAM =	1 - bo (1/cos i - 1)	bo Parameter	0.05

System loss factors

Wiring Ohmic Loss		Wires	19 m 3x2000 mm²	Loss Fraction	0.5 % at STC

User's needs : Unlimited load (grid)

PVSYST REPORT – RESULTS SUMMARY

The three main simulation results are clear

Grid-Connected System: Main results

Project :	**Atlanta Hartsfield Intl Ap_1MW**			
Simulation variant :	**Atlanta 1 MW - showcase losses (NOCT of 46 C)**			
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	OPT250-60-4-100	Pnom	250 Wp
PV Array	Nb. of modules	4004	Pnom total	**1001 kWp**
Inverter	Model	Sunny Central 500-HE-US	Pnom	500 kW ac
Inverter pack	Nb. of units	2.0	Pnom total	**1000 kW ac**
User's needs	Unlimited load (grid)			
Main simulation results				
System Production	**Produced Energy**	**1560 MWh/year**	Specific prod.	1558 kWh/kWp/year
	Performance Ratio PR	84.3 %		

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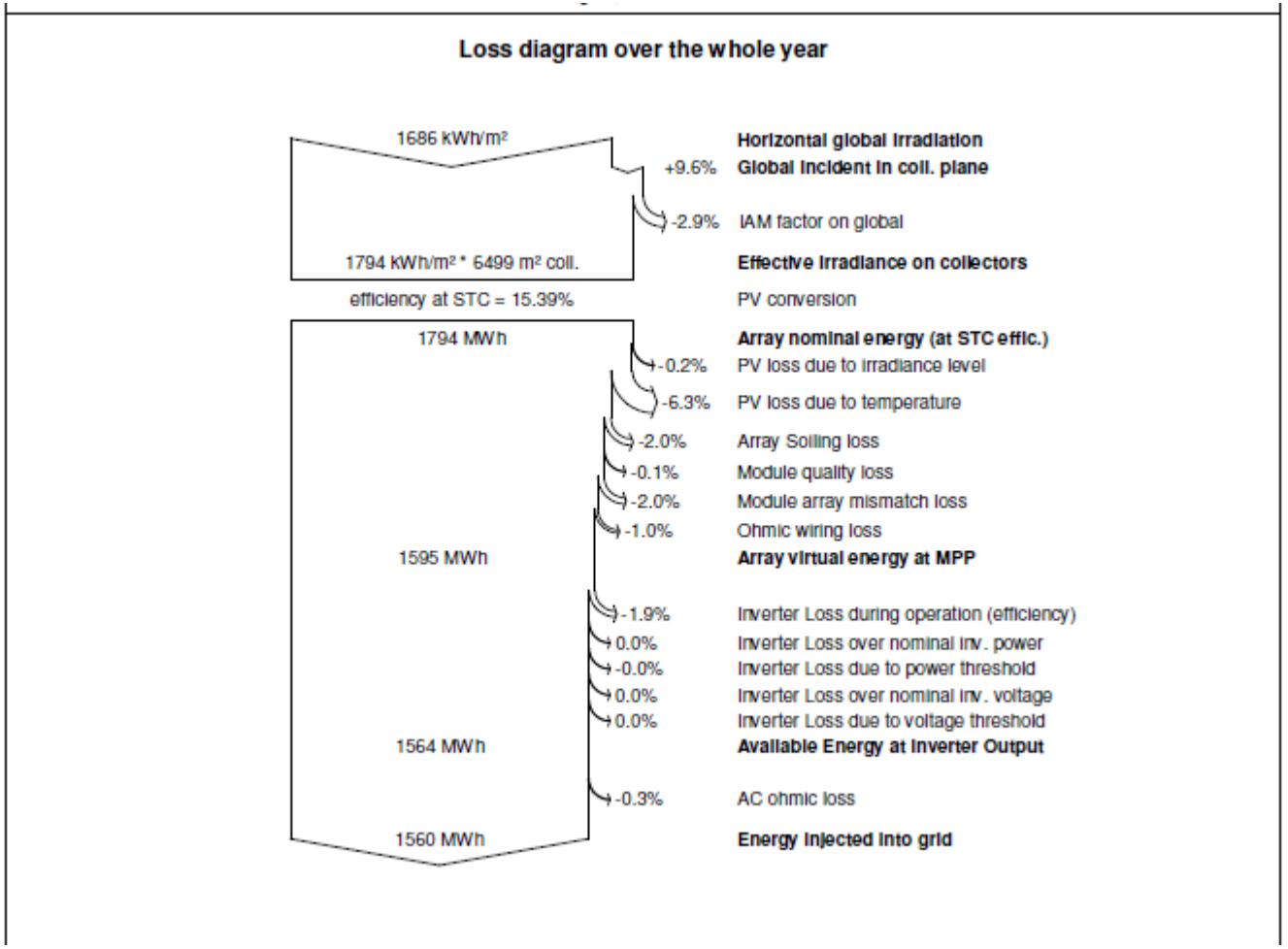
PVSYST REPORT – LOSSES

The loss diagram is very clear



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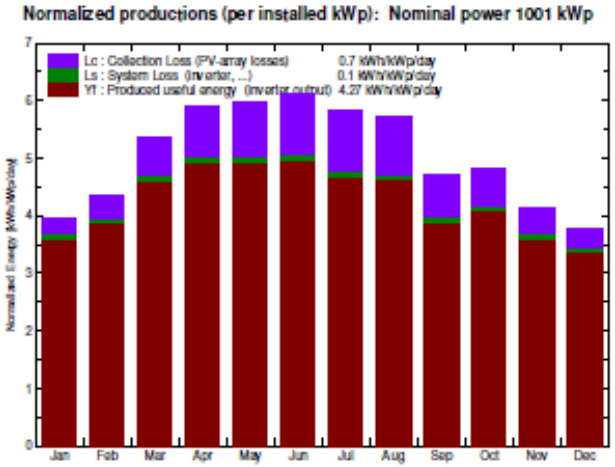
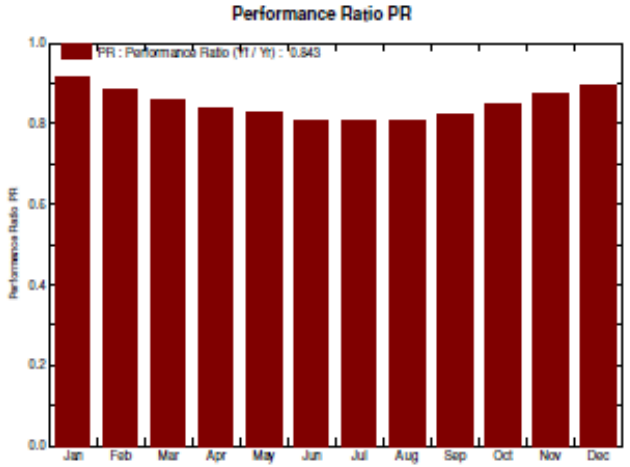
PVSYST REPORT – MONTHLY YIELD

Monthly breakdown of energy yield is presented in numerous formats





Atlanta 1 MW - showcase losses (NOCT of 46 C)
Balances and main results

	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	EffArrR %	EffSysR %
January	86.1	3.97	122.5	119.2	114.5	111.9	14.38	14.06
February	93.2	7.94	122.3	119.1	111.0	108.5	13.97	13.65
March	144.1	13.76	166.3	161.7	146.3	143.1	13.54	13.24
April	172.2	17.22	176.9	171.8	151.4	148.0	13.16	12.87
May	195.9	20.84	185.5	179.7	156.7	153.4	13.00	12.72
June	201.9	24.80	184.0	177.9	152.2	148.9	12.73	12.45
July	195.5	26.06	180.2	174.1	148.5	145.2	12.67	12.40
August	180.3	26.55	177.6	172.0	146.6	143.5	12.70	12.43
September	130.8	22.52	141.9	137.7	119.8	117.1	12.98	12.69
October	118.9	16.02	149.6	145.9	129.8	127.0	13.35	13.06
November	88.6	11.94	124.1	120.7	110.9	108.4	13.75	13.44
December	78.3	7.70	116.9	113.7	107.3	104.8	14.12	13.80
Year	1685.9	16.65	1847.9	1793.6	1594.9	1559.9	13.28	12.99

Legends: GlobHor Horizontal global irradiation; T Amb Ambient Temperature; GlobInc Global incident in coll. plane; GlobEff Effective Global, corr. for IAM and shadings; EArray Effective energy at the output of the array; E_Grid Energy injected into grid; EffArrR Effic. Eout array / rough area; EffSysR Effic. Eout system / rough area

RESULTS COMPARISON

	SAM 2012.5.11	PVSYST 5.56
Energy yield	1586.206 MWH/yr	1560 MWH/yr
Specific yield	1586 MWH/yr	1558 MWH/yr
Performance Ratio (PR)	88%	84.30%

If the derate-loss/parameters are set properly and the weather files are the same (TMY3 in this case) then both PVSYST and SAM give similar results (2% difference in this case).

PVSYST is a little more conservative and very close in comparisons with our field data.

Key is setting the parameters, accuracy of the panel and inverter models, and the validity of the weather file.

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TOOL COMPARISONS

	NREL SAM	PVSYST
Availability	Free and accessible to anyone in the world	For purchase/license only (30 day free full eval)
PV System Types	Grid-tie only for residential, commercial, commercial PPA, Utility Power Producer. No off-grid or hybrid.	Grid-tie, off-grid, and DC grid. No hybrid grid-tie + standalone.
Loss parameters	All required parameters are available	Extensive
Weather file support	TMY2, TMY3, EPW	Meteonorm, TMY2, TMY3, EPW, PVGIS, WRDC, Retscreen, Helioclim, SolarGIS
Default module database	CEC and Sandia performance models	Photon
Component database modification/creation	New version allows some flexibility in module creation. Not inverter or anything else.	Full flexibility for PV Module, Inverter, Charge Controller, Battery, and Generator
Overall ease of use	"straightforward" learning curve – data entry is highly graphical	"medium" learning curve
Customer facing reports	Clear and succint	Elaborate, professional, customizable
Economic/Financial Modeling	Very powerful, easy-to-use and easy-to-understand economic modeling	Difficult to understand economic modeling
Engineering Flexibility	Provides some degree of component modeling but limited thermal modeling	Very detailed component modeling with extensive thermal modeling

PRESENTER INFO

Sol Haroon is the lead systems engineer (EE) at Suniva, Inc. Suniva is a US manufacturer of high efficiency solar cells and PV modules. Sol is responsible for systems modeling, simulation, monitoring, design of PV systems, along with assessing the financial viability of systems entailing balance of system gear such as inverters and racking.

Sol is a solar professional, EV enthusiast, and a sustainable habitat systems architect working on net-zero architecture.

When not working and designing sustainable solutions, he enjoys volunteering with international humanitarian missions around the globe.

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